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SPECIFICATIONS AND CLAIMS OF PATENT APPLICATION

Power Cogeneration System And Apparatus Means For Improved High Thermal Efficiencies and Ultra-Low Emissions

BACKGROUND OF THE INVENTION

When Brayton Simple Cycle gas turbines operate as mechanical power drive sources to electric generators and other mechanically driven devices, atmospheric air is compressed and mixed with hydrocarbon gases or atomized hydrocarbon liquids for the resulting mixture's ignition and combustion at constant pressure. To produce power, the hot combustion and working motive fluid gases are expanded to near atmospheric pressure across one or more power extraction turbine wheels, positioned in series.

The majority of Brayton simple open-cycle aero-derivative-style low nitrogen oxide emission (that may hereafter be referred to as Low-NO.sub.x) current art gas turbines are predominantly presently limited in achieving shaft output horsepower rating with 26% to 39% thermal efficiencies, whereas most simple cycle industrial-style Low-NO.sub.x art gas turbines are predominantly presently limited in achieving shaft output horsepower rating with 27% to 34% thermal efficiencies. The aero-derivative turbine higher efficiencies are achieved when the gas turbines operate with compressor ratios ranging from 14 to 35 and predominant first stage turbine inlet temperatures ranging from 2000° to 2300° F.

Existing gas turbines employ combustion chamber air/fuel combustion chemical reactions, wherein the elements of time and high peak flame temperatures increase the presence of disassociation chemical reactions that produce the fugitive emissions of carbon monoxide (that may hereafter be referred to as CO) and other chemical reactions that produce nitrogen oxides (that may hereafter may be referred to as NO.sub.x).

The best available applied turbine low NO.sub.x combustion technology for limiting gas turbine NO.sub.x emissions, using stiochiometric air/fuel primary combustion reaction chemistry means, still results in the production of NO.sub.x and CO that are no longer acceptable for new power or energy conversion facilities in numerous states and metropolitan environmental compliance jurisdictions. With the current art gas turbine's use of compressed atmospheric air as a source of oxygen (that may hereafter be referred to as O.sub.2) which acts as a fuel combustion oxidizing reactant, the air's nitrogen (that may hereafter be referred to as N.sub.2) content is the approximate 78% predominant mass component within the cycle's working motive fluid. Due to its diatomic molecular structure, the nitrogen molecules are capable of absorbing combustion heat only through convective heat transfer means resulting from their collisions with higher temperature gas molecules or higher temperature interior walls of the combustion chamber.

Despite the very brief time it takes for a current art gas turbine to reach a average primary combustion zone gas resultant temperature of less than 2600° F within its combustion chamber, there are sufficient portions of the combustion zone gases that experience temperatures in excess of 2600° F to 2900° F for an ample period of time for the highly predominate nitrogen gas to enter into chemical reactions that produce nitrogen oxides. The same combined elements of time and sufficiently excessive high ~~flame~~ temperature permit carbon dioxide to enter into dissociation chemical reactions that produce carbon monoxide gas.

To achieve a goal of greatly reducing a turbine power unit's NO.Sub.x and CO fugitive emissions, it is necessary to alter both the fuel combustion chemical reaction formula and the means by which acceptable combustion chamber temperatures can be closely controlled and maintained within a power turbine unit's fuel combustion chamber assembly. Maintenance of an acceptably low selected fuel combustion peak gas temperature at all times and throughout all portions [[~~of~~]] within the combustion chamber assembly, requires a change in the means by which the heat of combustion can be better controlled and more rapidly distributed uniformly throughout the gases contained within the fuel combustion chamber assembly.

To achieve a goal of significantly reducing a turbine power cogeneration system's mass emission rate of the "greenhouse gas" (otherwise referred to as carbon dioxide or that may hereafter be referred to as CO.sub.2) by a desired percentage amount, it is necessary to proportionally increase the thermal efficiency of a power cogeneration system which therein proportionally reduces the amount of combusted hydrocarbon fuel required to provide the energy conversion into a given amount of required work and usefully applied residual heat energy.

It has been well known and practiced for decades that higher humidity air and injected water or steam commingled with conventional air combustion gases increases combustion flame speeds and fuel combustion thermal efficiencies within gas turbines and other fuel combustion heater-burner apparatus using air/fuel combustion. It has also been well known and practiced that partially re-circulating combustion exhaust or flue gases containing carbon dioxide and water vapor back into a combustion chamber results in a reduced level of nitrogen oxides within the fuel combustion exhaust gases. Due to the high temperatures and speed of completed fuel combustion, the scientific community has been unable to reach a consensus as to precisely what series of altered chemical reactions occur when water vapor and/or carbon dioxide is introduced into a turbine combustion chamber.

Oxy-fuel combustion heater-burners have been employed for many years in the steel and glass making industries to furnish desired 3000+ degree Fahrenheit combustion gas temperatures into furnaces to avoid the production of high NO.Sub.x emissions (but at the expense of high CO emissions). Both the present air separation art methods' high energy costs of producing acceptable combustion grade oxygen, and the lack of devised combustion system methods to control preset desired oxy-fuel combustion heater-burner or combustion chamber uniform maximum temperatures, have curtailed oxy-fuel combustion applications within present energy conversion facilities.

Current art gas turbines must be de-rated from their standard ISO horsepower or kW ratings at ambient temperatures exceeding 59° F, or at operating site altitudes above sea level. Thus, during summer's peak power demand periods, when the ambient temperature can increase to 95° F, 12% to 18% horsepower derations of a conventional gas turbine's ISO rating can occur. It is obviously desirable that a power turbine/generator unit within a cogeneration system not be susceptible to such on-site ambient temperature derations when peak power demands occur.

The current and future projected increasing costs of purchased utility electric power and natural gas (or liquid hydrocarbon fuel) and the accepted projected future trend in the future of "distributed power" facilities, coupled with present and future environmental constraints on fuel combustion exhaust emissions, will make it commercially mandatory that such "distributed power" facilities have the combined attributes (at the minimum) of combined ultra-low NO.sub.x and CO exhaust emissions and substantially higher thermal efficiencies than offered by current art turbine power cogeneration systems. It can be expected that the number of new turbine powered 'cogeneration system' facilities in the world will be significantly greater than the number of turbine powered 'combined-cycle' facilities that are devoted purely to the production of electric power. The referenced 'cogeneration system facilities' are not new in concept. Such facilities became highly

popular in the 1970's (then referred to as 'Total Energy Plants') and were aggressively promoted by many natural gas utilities. Reciprocating gas engine-driven generator sets were the predominant producers of prime power and utilized waste heat. These 'Total Energy Plant' facilities efficiently provided electricity, hot water or steam for domestic hot water and building heating requirements, and chilled water for air conditioning. 'Total Energy Plants' were widely applied to serve hospitals, universities, large office buildings or building complexes, shopping centers, hotels, food processing plants, multi-shift manufacturing and industrial facilities, etc. The 50 plus years old predecessor to the 'Total Energy Plant' concept was the central electric power and steam plants that continue to currently serve some large eastern US cities, and more predominantly European cities and metropolitan areas. Predominantly, 'Total Energy Plants' and current cogeneration facilities have had less than 100 psig utility supplies of natural gas available to their facilities.

Summary of the Invention

To achieve both power turbine ultra-low NO.sub.x and CO exhaust emissions (as well as reduced "greenhouse gas" CO.sub.2 and enhanced simple-cycle operating thermal efficiencies, the inventor's AES turbine cycle system and apparatus is described in U.S. Patent #6,532,745 dated March 18, 2003. The cited invention's further described partially-open gas turbine cycle contains multiple heat recovery devices for transferring waste heat to varied process gases and steam resulting in a cogeneration facility overall maximum thermal efficiency that "may approach 100%".

The present invention describes the means by which the cited partially-open AES turbine cycle system and apparatus can be incorporated into a simplified and improved gas turbine cogeneration system having simplified apparatus means and that can further achieve increased turbine cogeneration system thermal efficiencies which can exceed 115%.

The present invention further describes the alternative system and apparatus means for the cited improved partially-open turbine cogeneration system that can be employed within a desired power cogeneration system design, the said alternative system and apparatus means incorporating portions of the heater cycle system and apparatus content cited in the inventor's U.S. Patent application 10/394847 filed March 22, 2003 and subsequently allowed for present pending US patent publication, titled "Partially-Open Fired Heater Cycle Providing High Thermal Efficiencies and Ultra-Low Emissions". The addition of these alternatives to the presented turbine based cogeneration system, as later further described and shown in Figure 2, can increase the presented cogeneration system's overall thermal efficiency to greater than 115%.

The commercial viability of achieving maximum reductions in the presented invention's enhanced cogeneration system's fuel operating costs and accompanying reduced NO.sub.x, CO, and CO.sub.2 exhaust emissions are assured by the presented invention's oxy-fuel combustion system's access to a facility-provided ultra-high electric energy efficient modular air separation system providing a 93% to 95% purity predominant oxygen fuel oxidizing stream, such as presented in the inventor's U.S. Patent Application 10/658157 dated September 9, 2003 and titled "Pure Vacuum Swing Adsorption System and Apparatus" that can provide a 75% reduction in kWh/Ton of produced predominant oxygen gas mixture, the application subsequently granted US Patent # 6,878,186 dated April 12, 2005.

To achieve the cogeneration system's ultra-low fugitive exhaust emissions, the cited partially-open power cogeneration system and apparatus means provides a continuous controllable mass flow rate of recycled superheated vapor-state predominant mixture of carbon dioxide and water vapor (that may hereafter be referred to as H.sub.2 O), in identical mixture Mol percent proportions as each occurs as products of chemical combustion reactions from the gaseous or liquid hydrocarbon fuel employed.

To achieve the cogeneration system's ability to employ gaseous hydrocarbon fuels, other than gas utility distribution quality natural gas, gaseous fuels (containing toxic and/or difficult to combust hydrocarbon molecular gases) can be rapidly carried through useful heat conversion and/or completed incineration with the inventions provided system and apparatus means to control the primary combustion zone temperature. Whereas the invention example system's presented controlled gas mass flow rates and temperatures are capable of producing and exhausting 1800°F combustion chamber assembly gas temperatures to the <u>power</u> turbine assembly (while maintaining herein described high thermal efficiencies and ultra-low emissions), the preferred example 2400° F primary combustion zone temperature may achieve a desired 7.585 greater chemical reaction rate than that occurring at 1800° F. As repeatedly verified by John Zink Research in applied research, the reaction rate formula is:

$$\text{Reaction Rate Increase} = (N) = \frac{[(2400^{\circ}\,F + 460) \div (1800^{\circ}\,F + 460)] - 1}{.035}$$

Provided herein is both a partially-open turbine power cogeneration system with apparatus means for use therein of either modified current type gas turbine unit configurations, or alternative turbine assembly unit apparatus configurations that can utilize separate existing low cost mechanical equipment components and combustion chamber assemblies which are predominantly not designed for, nor applied to, the manufacture of current art gas turbines nor the said components and combustion chamber assemblies incorporation into facility designs of current technology gas turbine cogeneration systems.

The invention's combined employed cited partially-open gas turbine cycle system and apparatus and alternative added cited heater cycle system stream and apparatus portion into the present invention therein provides for a commonly 'shared non-air' working motive fluid means that is essential to the 95% to 100% reduction of NO.sub.x, and CO mass flow emissions from

those of current art Low-NO.sub.2 designed gas turbines and other conventional fuel combustion heater-burner devices that can be applied within existing art power cogeneration systems.

It is an first objective of the present invention's improved power cogeneration system and apparatus means to provide a new benchmark standard for Best Available Technology (hereafter may be referred to as B.A.T.) in achieving combined highest thermal efficiencies, lowest emissions, and lowest auxiliary facility operating power consumptions within an overall operating power cogeneration facility.

It is a second objective of this invention to provide the means by which the power cogeneration system's production of steam or hot water, and/or the heating of process fluids, is not limited by the amount of a turbine/generator or mechanical drive train's available exhaust waste heat derived from a given production level of electric power or mechanical horsepower.

It is a third objective of this invention to provide the means by which the power cogeneration system's presented alternate apparatus can comprise current art individual power train unit components that can be adapted to individual unit power generator ratings of 200 kW to 30 MW+ to satisfy most cogeneration facilities' installed individual unit rating requirements.

It is a forth objective of this invention to provide the collective means by which deviations from the presented invention's example operating conditions can be made to best accommodate a facility designer's incorporation of existing models of other facility auxiliary equipment that can be further incorporated into a specific design of cogeneration facility, such as currently manufactured absorption chillers or mechanically-driven refrigeration chillers that have been conventionally or similarly applied in related waste heat recovery power facilities for over 30 years.

It is a fifth objective of the present invention's cogeneration system and apparatus means to accomplish both a highly accelerated oxy-fuel combustion process and the added means to separately control a preset maximum primary combustion zone temperature and the tertiary zone

exhaust gases temperature supplied to the hot gas expander power turbine assembly. This satisfied objective eliminates the elements of sufficient time and high degree of temperature that is required for endothermic dissociation chemical reactions to occur that produces both NO.sub.x and CO within the primary combustion zone product gases.

It is a sixth objective of the present invention of improved system and apparatus means that a power system modified current art gas turbine assembly or alternative new style re-configured turbine train assembly can be capable of achieving an additional 35% to 40% in power cogeneration system thermal efficiencies than are available in current art B.A.T. gas turbine powered cogeneration facilities.

It is a fifth objective of the present invention of improved system and apparatus means that the cited incorporated partial-open gas turbine cycle system and apparatus means of preferred high efficiencies can employ but not be limited to gas compression ratios of 2.4 to 6.4 (2.1 to 6.5 Bar operating pressure) as compared to current art individual gas turbines that may have a compression ratio ranging between approximately 9 to 35.

It is a sixth objective of the present invention of improved system and apparatus means that the cited partial-open gas turbine cycle system and apparatus can provide the maximum cogeneration thermal efficiencies with facility fuel gas supply pressures of less 100 psig (6.9 bar).

It is a seventh objective of this invention to provide the means wherein, during a steady-state power operation, that the atmospheric vented and open cycle portion of the cogeneration system recycled exhaust mass flow can be approximately 5 to 8% of the total working motive fluid mass flow rate as contained within the closed portion of its turbine power cogeneration system.

It is a ninth objective of this invention to provide the means whereby both the cited partial-open AES turbine cycle system and apparatus as applied within the present invention of improved cogeneration system efficiency, and the alternative cogeneration system apparatus means described

herein, can include appropriate safety sensor and system fluid flow control device means. Both the presented invention's cogeneration system and apparatus component means and the separately associated cogeneration power plant auxiliaries can be monitored and controlled for safe operation, as well as having provided means for controlling the cogeneration system's individual system fluid flows in response to changes in electric power generation demands and effective heat extraction demands by supplied steams of steam or hot water, or process fluids.

It is a tenth objective of this invention to provide the apparatus and control means by which a non-distribution quality of gaseous hydrocarbon fuel (containing toxic and/or difficult to combust hydrocarbon molecular gases) can be rapidly carried through oxy-fuel combustion to a useful heat conversion and/or completed incineration.

The following nine Embodiments comprise the subject matter of the invention:

First Embodiment

The working motive fluid of this invention's turbine cogeneration system comprises a continuous superheated vapor mixture of predominant carbon dioxide and water vapor in identical Mol percent ratio proportions as the CO.sub.2 and H.sub.2 O molecular combustion product components are produced from the combustion of the gaseous or liquid hydrocarbon employed fuel.

Within the predominately-closed portion of the presented cogeneration system and apparatus, the re-circulated turbine exhaust gas is routed from an exhaust gas distribution manifold containing exhaust gas having a small degree of superheat temperature and positive gage pressure supply with connectivity to the inlet of the primary recycle compressor. The exhaust gas recycle compression function can be performed by a more typical axial compressor section used for air compression within a current art gas turbine unit, or it may be a separately means-driven

compressor of the axial, centrifugal, or rotating positive displacement type. Either means of compression can incorporate means of flow control available within the compressor or by its driver's varied speed, with flow changes being initiated by a master system control panel containing programmable microprocessors.

The compressor can increase the recycled turbine exhaust's absolute pressure by a ratio range of only 2.4 to 6.4 to achieve a preferred high simple-cycle thermal efficiency, but the cycle is not limited to operations within these said ratios.

As shown in Table 1, between gas turbine fuel combustion pressures of 45 psia and 75 psia, the AES Turbine Simple Cycle thermal efficiencies portion of the cogeneration system can range between 35.16% and 43.24%. Between 75 psia and 90 psia oxy-fuel combustion chamber assembly pressures (with the common primary recycle compressor and power turbine efficiencies of 84% and stage 1 turbine inlet temperature of 1800° F), the AES turbine cycle system portion (simple-cycle) efficiencies begins to decline.

TABLE 1

Combustion Operating Pressure	Gas Turbine Gas Inlet Temperature	Gas Turbine Exhaust Temperature	Gas Turbine Net Output Horsepower	Gas Turbine Fuel Rate Btu/HP-Hr.	Thermal Efficiency %*
45 psia	1800° F	1471° F	2859	7237	35.16
60 psia	1800° F	1391° F	3458	5983	42.54
75 psia	1800° F	1331° F	3515	5885	43.24
90 psia	1800° F	1284° F	3406	6075	41.89

*With a 1 Mol/minute methane gas fuel rate

The re-cycled and re-pressurized turbine exhaust gas (that hereafter may be referred to as "primary re-pressurized recycle gas") is discharged from the primary recycle compressor at an increased temperature and pressure through a conduit manifold containing both a side-branch

connection and first and second parallel conduit end-branches flow-controlled streams. The conduit manifold side-branch supplied controlled low mass flow stream of primary re-pressurized recycle gas can be reduced in temperature within an air-cooled exchanger prior to the stream flow's entry into one or more preferred partial premixer subassembly contained within each oxy-fuel combustion chamber assembly. Within each referred partial premixer subassembly, the primary re-pressurized recycle gas stream can be homogenously pre-mix blended with the supply stream of predominant oxygen that is also is also supplied to the preferred partial ~~pre-mix~~ premixer subassembly and/or the supply stream of fuel.

The cited first and second parallel conduit end-branches flow-controlled streams having end-connectivity respectively to the inlets of first and second headers of the power turbine exhaust gas waste heat recovery unit (WHRU) exchanger of counter-current flow gas to gas heat exchange design. A predominate flow-controlled portion of the hot gas expansion power turbine's developed high temperature exhaust is flow-directed through this WHRU exchanger for its heat transfer into the primary recycle gas stream that thereafter is downstream re-admitted into the oxy-fuel fired combustion chamber assembly.

This hot gas expansion power turbine exhaust gas WHRU exchanger can be capable, with the particular example of a methane fuel combustion chamber pressure of 60 psi absolute and 1800° F first stage power turbine inlet temperature, of raising the temperature of the primary re-pressurized recycle gas within the turbine exhaust gas WHRU exchanger to an approximate maximum 1350° F temperature. With these operating conditions and assumed compressor and hot gas expansion turbine efficiencies of 84%, a desired simple-cycle turbine thermal efficiency of 42.5% can be achieved.

Thereafter, the 1350° F highly superheated and re-pressurized primary recycle gas individual streams are referred to as "working motive fluid". The first controlled stream of working

motive fluid can be routed and separately flow-divided as required to the internal tertiary blending zone contained within each of one or more oxy-fuel fired combustion chamber assembly that can be positioned radially about the centerline axis of the power turbine unit assembly. The second controlled stream can be separately flow-divided as required for passage into one or more preferred partial premixer sub-assemblies contained within one or more oxy-fuel fired combustion chamber assembly.

Within the presented power cogeneration system, a lesser flow controlled portion of the total power turbine exhaust flows through the waste heat recovery steam generator (that hereafter may be referred to as WHRSG) exchanger or waste heat recovery process fluid (that hereafter may be referred to as WHRPF) exchanger.

Second Embodiment

From the First Embodiment's "the re-circulated turbine exhaust gas is routed from a exhaust gas distribution manifold containing exhaust gas having a small degree of superheat temperature and positive gage pressure supply with connectivity to the inlet of the primary recycle compressor", the cited re-circulated turbine gas within the exhaust distribution manifold comprises the discharge exhaust gas from a second WHRSG or WHRPF exchanger upstream connected to a re-circulated exhaust gas manifold that conveys the combined turbine reduced temperature exhaust gases from both the WHRU exchanger and the first parallel-positioned WHRSG or WHRPF exchanger into which the total gas turbine high temperature exhaust is first inlet-connected.

Either the second WHRSG or second WHRPF exchanger can perform the initial heating of supplied streams from either a facility's steam or hot water feed circuit or a process fluid stream prior to either of these streams being further downstream flow-connected to the fore-described high temperature turbine exhaust gases first WHRSG exchanger or WHRPF exchanger.

Third Embodiment

From the First Embodiment cited re-circulated turbine exhaust from the exhaust gas distribution manifold supplied to the inlet of the primary recycle compressor, the exhaust gas distribution manifold has a end manifold alternative system connection point and two side-branch flow delivery connections. The first side-branch conduit provides the greatly predominant flow of re-circulated exhaust gases into the inlet of the recycle compressor, and the second side-branch conduit directs the controlled flow of excess re-circulated turbine exhaust gases to atmosphere during steady-state operation of the presented system. This flow of excess re-circulated turbine exhaust gases to atmosphere constitutes the "Open Portion" of the presented partial-open power cogeneration system. The system steady-state condition's controlled mass flow rate in which the excess re-circulated turbine exhaust is vented to atmosphere is equivalent to the combined mass rates at which the fuel and the predominant oxygen gas streams enter the invention's provided oxy-fuel combustion system and apparatus means.

Fourth Embodiment

From the First Embodiment cited "The second controlled stream can be separately flow-divided as required for passage into one or more preferred partial premixer sub-assemblies contained within one or more oxy-fuel combustion chamber assembly", each partial premixer sub-assembly having the following introduced controlled streams: fuel; a predominant oxygen stream which originates from an adjacent facility area containing a preferred highly electric energy efficient modular air separation system; First Embodiment described air-cooled primary re-pressurized recycle gas; and second stream of working motive fluid. These individual flow controlled conduit streams at differential pressures and velocities are collectively admitted through their respective partial premixer inlet conduit means for preferred selective pre-mixing and homogeneous blending at points of admittance into the primary combustion zone within each oxy-fuel combustion

chamber assembly. The cited specific individual gaseous stream mass flows, temperatures and pressures entering the invention's combustion chamber assembly are provided in Table 2 in the following 'Detailed Description of the Preferred Embodiment'.

Fifth Embodiment

From the First Embodiment cited "The first controlled stream of working motive fluid can be routed and separately flow-divided as required to the internal tertiary blending zone contained within each of one or more oxy-fuel combustion burner assembly that can be positioned radially about the centerline axis of the power turbine assembly", the first controlled stream of working motive fluid supplied to the tertiary blending zone flow can be first introduced into an oxy-fuel combustion chamber assembly's inner annulus area between the combustion chamber assembly's outer casing and a current art style inner liner surrounding each tertiary blending zone within each combustion chamber assembly. This tertiary zone introduced mass flow of superheated working motive fluid of example 1350°F temperature blends therein with the example maximum 2400° F resultant temperature combined gases emanating from the combustion chamber assembly's primary combustion zone, the combined gases thereby producing a resultant example 1800° F final oxy-fuel combustion chamber assembly exhaust flow temperature connecting to the hot gas expansion turbine assembly. The blended temperature of the final oxy-fuel combustion chamber assembly exhaust gases is not limited to 1800° F, and can be controlled by the tertiary zone's cited introduced first stream's working motive fluid mass flow rate to establish any other higher or lower selected operating temperature. The example 1800°F temperature can be chosen to coincide with 10 year old proven power turbine blade metallurgy technology for continuous operation.

Within the one or more hot gas expansion turbine stages, the oxy-fuel combustion chamber assembly's pressurized and highly superheated gases are expanded to create useful work in the established form of both turbine output shaft horsepower and (in the case of a current art gas

turbine unit configuration) internal horsepower to additionally direct-drive the primary recycle gas compressor. In a current art 2-shaft style of gas turbine, the primary recycle gas compressor is shaft-connected to the high-pressure stage section of the hot gas expansion power turbine assembly, and the low pressure section of the hot gas expansion power turbine assembly provides the turbine power output power to driven equipment. The expanded exhaust gases exit the hot gas expansion power turbine assembly at a low positive gage pressure and are further conveyed through conduit means to the fore-described WHRU exchanger and adjacent parallel-position WHRSG or WHRPF exchanger as further described later and shown in Figure1.

Sixth Embodiment

In the Fifth Embodiment description "In a conventional 2-shaft style of gas turbine, the primary recycle compressor is shaft-connected to the high-pressure stage section of the hot gas expansion power turbine assembly, and the low pressure section of the hot gas expansion power turbine assembly provides the turbine power output power to driven equipment.", the presented invention provides alternative system and apparatus means by which an unconventional configured turbine power train comprising; individual separate compressor unit assembly, oxy-fuel combustion heater-burner assembly, and a hot gas expansion turbine assembly unit with mechanical shaft output can be configured to produce mechanical or electrical power within a cogeneration system as described later and shown in Figure 2.

The invention's alternative primary recycle compressor can be a separately motor-driven or stream turbine-driven compressor of centrifugal or axial type therein comprising one or more stages of compression as required, or a single rotating positive displacement type for the system applied operating conditions. The re-circulated and slightly superheated turbine exhaust gas stream is re-introduced into the primary recycle gas compressor and increased in pressure and temperature as described for the current art gas turbine power system. This style of primary recycle gas

compression drive train generally offers greatly improved capacity control and/or turn-down capabilities, but can be overall less efficient than the conventional gas turbine assembly's direct-driven axial compressor section.

As described in the Fourth and Fifth Embodiment, the oxy-fuel combustion chamber assembly configuration and functional operation remains unchanged. Rather than the Fifth Embodiment described one or more oxy-fuel combustion chamber assembly being positioned radially about the centerline axis of the power turbine assembly, the presented invention's alternative system and apparatus means can further have a single oxy-fuel fired combustion heater-burner assembly that is axially centerline-positioned and can be directed-connected to the hot gas expander power turbine as shown later in Figure 2. A single oxy-fuel combustion heater-burner chamber assembly can comprise multiple elements of existing manufactured oxy-fuel heater-burner combustor models rated from 0.6 to 14 MM Btu/Hr. as typically employed in the glass and steel making industries., or can comprise modifications to existing single industrial steam generation or process heater burner configurations that can be rated between 25 to 500 MM Btu/Hr.

Seventh Embodiment

From the Second Embodiment's cited "...., the ~~said~~ cited re-circulated turbine gas within the exhaust distribution manifold comprises the discharge exhaust gas from a second WHRSG or WHRPF exchanger upstream connected to a re-circulated exhaust gas manifold that conveys the combined turbine reduced temperature exhaust gases from both the WHRU exchanger and the first parallel-positioned WHRSG or WHRPF exchanger into which the gas turbine high temperature exhaust is first inlet-connected.", the total amount of waste heat that can usefully be transferred into the cited heat exchangers' supplied fluids is limited to or in proportion to the amount of turbine output power that is developed by the invention's power cogeneration system turbine unit.

The presented invention provides alternative system and apparatus means by which a power turbine cogeneration system's production of steam or water (or heating of process fluids) is independent of the amount of turbine developed power within a cogeneration system. This presented invention, with its described alternative system and apparatus means, provides this cogeneration system with added operational flexibility while further increasing the thermal efficiency of the presented invention's cogeneration system and maintaining the same ultra-low exhaust emissions. Wherein a presented cogeneration system facility of a given power output rating could fully utilize a 100% or greater steam production or process fluid heating than would be associated with the cogeneration system and apparatus means shown in Fig. 1, the Fig. 2 presented alternative cogeneration system and apparatus means can include the presented supplementary oxy-fuel fired heating of recycled system exhaust gases to achieve the additional production of steam or process fluid heating while achieving the presented overall cogeneration system thermal efficiencies that can significantly exceed 115% as shown later in Table 5 for an example 100% increase in steam or process heating beyond the Fig. 1 system capabilities.

The presented invention's alternative system and apparatus means includes the added conduit means for withdrawal of re-circulated turbine exhaust gas from the Third Embodiment described exhaust gas distribution manifold for the conduit routed supply of the re-circulated turbine exhaust gas to the example Fig.2 preferred two parallel auxiliary primary recycle blowers. The blowers can be separately capacity controlled to produce slightly re-pressurized first and second conduit stream flows of exhaust recycled gas that are connected to the alternative cogeneration system's auxiliary oxy-fuel combustion heater-burner assembly unit. The oxy-fuel combustion heater-burner assembly employs additional individual connected flow controlled streams of fuel and predominant oxygen to produce an identical composition of combustion exhaust gases as existing within the turbine exhaust gases, whereby the cited added oxy-fuel combustion heater-

burner assembly's exhaust gases are conduit routed into the turbine exhaust conduit branch connecting to the WHRSG exchanger or WHRPG exchanger described above in the above cited Second Embodiment text.

In the case of the Fig. 1 configuration of the presented invention's cogeneration system and apparatus means, any increase in power generation (beyond the then existing cogeneration system's 'steady-state' production condition, but not exceeding the turbine's continuous rating) can be accomplished by terminating the controlled flow of vented excess turbine re-circulated exhaust flow to atmosphere and increasing fuel and predominant oxygen flow. Only upon reaching the required accumulated increased mass flow of preset high temperature exhaust gases within the closed system, is the presented invention's power cogeneration system then returned to its normal 'steady-state' and 'partially-open system status' with controlled excess re-circulated exhaust gas vented to atmosphere.

Eighth Embodiment

From the First Embodiment cited "As shown in Table 1, between a power turbine oxy-fuel combustion chamber assembly pressures of 45 psia and 75 psia, the AES turbine Simple Cycle thermal efficiencies can range between 35.16% and 43.24%", the invention's improved high thermal efficient cogeneration system's presented example of a 60 psia oxy-fuel combustion burner assembly can enable a low fuel gas supply pressure of less than 65 psi gage (5.5 Bar) to be employed.

Ninth Embodiment

From the preceding collective Embodiments' cited control of fluid stream flows, temperatures, pressures, generated power, and apparatus means including valves, compressors, blowers, motors, etc., the presented invention's cogeneration system and apparatus means can be

both performance and safety monitored and controlled by a manufacturer's PLC based control panel design.

Overall System and Apparatus Means

Within the presented partially-open turbine power cogeneration system and apparatus means described herein, the provided system employed oxy-fuel combustion generated working motive fluid means can provide a 95 to 100% reduction of NO.sub.x that occurs within current art Low-NO.sub.x gas turbines.

The provided partially-open turbine power cogeneration system's temperature controlled oxy-fuel combustion temperature and the speed of completed combustion heat transfer also similarly suppresses the chemical reaction dissociation formation of the fugitive emission CO from CO.sub.2. The means of suppressing the development of fugitive emissions results from the following collective working motive fluid molecular attributes and combustion events:

(a) The working motive fluid of this invention's power cogeneration system comprises a continuous superheated mixture of predominant carbon dioxide and water vapor in identical Mol percent ratio proportions as these molecular components are produced from the combustion of a gaseous or liquid hydrocarbon fuel. For example, in the case of landfill gas, the working gas fluid contains a 1:1 ratio of 2 Mol carbon dioxide to 2 Mols water vapor in identical proportion to the products of stoichiometric oxygen combustion. The chemical reaction equation can be described as follows:

Working Motive Fluid + 1 Mol CH.sub.4 + 1 Mol CO.sub.2 + 2 Mols O.sub.2 =

2 Mol CO.sub.2 + 2 Mol H.sub.2 O + Heat + Working Motive Fluid.

In the example of methane gas fuels, the working fluid composition contains a ratio of 1 Mol CO.sub.2 to 2 Mols H.sub.2 O in identical proportion to the products of 105% stoichiometric oxygen combustion of methane fuel within the chemical reaction equation of: